

Mangroves: The Tidal Forest

The word "mangrove" is a term used to describe a diverse group of plants that are adapted to a wet, saline habitat. Typically it refers to an individual species of salt tolerant plants of tropical and subtropical intertidal regions of the world. These are the plants which live at the edge of the sea and they not only have an interesting morphology and anatomy but also constitute a peculiar ecosystem which is extremely sensitive and fragile and equally productive like rain forest. The book would help in understanding the ecological role and economical value of mangrove forests and why they need to be protected.

About the author

After completing his M.Sc and Ph.D in Botany from Annamalai University, Dr. R. Panneerselvam joined the Botany department as a Lecturer, where he is now heading the department. His specialization is environmental physiology and Bio-diversity. Apart from authoring a large number of research papers in various scientific journals, he has edited science text books at various levels. He evinces keen interest in popularizing science at school and college level.

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VIGYAN PRASAR

(Department of Science & Technology, Govt. of India)
A-50, Institutional Area, Sector-62, NOIDA 201307
Phone: 91-120-240 4430,35 Fax: 91-120-2404437
e-mail : info@vigyanprasar.gov.in
Website : <http://www.vigyanprasar.gov.in>

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R. Panneerselvam



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Foreword

Earth is the only planet we know of with life on it. Animals, Plants and microorganisms maintain a delicate balance with a variety of life forms we call Biodiversity. Each species depends on other species for its existence. When we talk of life on earth, we also talk about the human species. If we need to understand and preserve our environment, we shall need to understand the interdependence of the species on each other and the importance of natural resources like air, water and soil for living beings.

Life has continued to evolve on this earth over millions of years adapting to changing environment. Only those species have survived that have adapted to the changing environment. This change could be due to natural causes like earthquakes, eruption of volcanoes, cyclones, and so on. It even could be due to climate change. However, quite often this change is brought about by the species higher up in the ladder of evolution that tries to control environment to suit its needs and for development. This is precisely what human species has done to our fragile planet.

We need energy for development; which we traditionally obtain by burning natural resources like

firewood, coal and petroleum. This is what we have been doing for centuries. Today there is consensus that human activities like burning of fossil fuels and consequent pumping of gases like carbon dioxide into atmosphere have been responsible for the earth getting hotter and hotter. Today, there are threats to our planet arising from climate change, degrading environment, the growing rate of extinction of species, declining availability of fresh water, rivers running dry before they can reach sea, loss of fertile land due to degradation, depleting energy sources, incidence of diseases, challenge of feeding an exponentially growing population, and so on. The human population is now so large that the amount of resources needed to sustain it exceeds what is available. Humanity's environmental demand is much more than the earth's biological capacity. This implies that we are living way beyond our means, consuming much more than what the earth can sustain.

To draw the attention of the world to these aspects and in an attempt to establish that environment is where we live; and development is what we all do in attempting to improve our lot, within that abode, the United Nations has declared the year 2008 as "The Year of the Planet Earth". It is hoped that with the cooperation of all we shall be able to save the biodiversity and the life on this planet. A host of activities and programmes are being organized all over the world for this purpose. One of the important aspects is to make people aware about the challenges we face and the possible solutions to save this planet from heading towards catastrophe. It is with such thoughts that Vigyan Prasar has initiated programmes with activities built around the theme "The Planet Earth". The activities comprise of

development and production of a series of informative booklets, radio and television programmes, and CD-ROMs; and training of resource persons in the country in collaboration with other agencies and organizations.

It is expected that the present series of publications on the theme "The Planet Earth" would be welcomed by science communicators, science clubs, resource persons, and individuals; and inspire them initiate actions to save this fragile abode of ours.

Vinay B. Kamble
Director, Vigyan Prasar
New Delhi

Preface

At some time or the other, we have all been amazed by the magnificent architecture of Mother Nature. In my childhood, I was astonished to see the great profusion of plant and animal life all around me. I used to bombard my parents and my science teacher with questions about them. The puzzle that confronted me was centred around how plants could be distinct from one another? It was a question my young brain wanted to resolve.

I got a chance to do that when I was taken on an educational tour to Kodaikanal (Western Ghats). I had a chance to really enjoy the forest ecosystem for the first time. It was a hands-on experience that opened my eyes to the grand scheme underlying the natural world. From that moment onwards I perceived that a forest connects the sky and the soil. It contains gigantic trees that rise up from the surface of the earth, even as the roots anchor it in deep in the soil, while the crowns of leaves reach out towards the shining sun. The realization that all the threads of nature are interconnected was a lesson that I never forgot.

On another occasion, I had the opportunity to visit Pichavaram. I was still a child and enthralled to sail in a

small boat down the narrow clustered canals. There seemed to be a special type of plant growing on the banks of the salt water canals hugging the sea. I was thrilled when the leaves caressed my head as we passed beneath the overhanging branches. My father told me that this is a type of vegetation called the mangrove. He called it a mangrove forest. I remember the feeling of confusion that was generated in my tender mind at the use of the word "forest". Till then my idea of the word had been distinctly different from what I was seeing. Even the type of trees making up this 'forest' was distinct from, what my mind conceived of, as typical forest trees. It triggered an interest that would stay with me all my life.

The plants living at the edge of the sea aroused my curiosity, which I have had the opportunity to sate by studying them over the years. I can confidently say that the combination and variety of morphological and physiological adaptations found in this diverse and unique group of plants has no equal. I would like to share my knowledge about mangroves in this booklet and I hope the fascinating facts enchant other minds as they have mine.

R. Panneerselvam



Introduction

The word "Mangrove" is a combination of the Portuguese word "*Mangue*" and the English word "grove". The word 'Mangrove' is a term used to describe a diverse group of plants that are adapted to a wet, saline habitat. The term may also, typically, refer to an individual species. Mangrove plants are thus, salt-tolerant plants of tropical and subtropical intertidal regions of the world. This diverse group of plants has been categorized as (i) true mangroves and (ii) mangrove associates.

Mangroves establish coastal wet lands forests at the intertidal zones of estuaries, back waters, deltas, creeks, lagoons, marshes and mud fields of tropical and subtropical regions of the world. The specific regions where these plants occur are termed as mangrove ecosystem. Despite these divisions, it is sometimes difficult to precisely define a mangrove species.

Terms such as mangrove community, mangrove ecosystem, mangrove forest, mangrove swamp and *mangal* are used interchangeably to describe the entire mangrove community. Mangrove forests include taxonomically diverse plants but all these species exhibit certain common special adaptive features. Besides mangroves, the ecosystem also

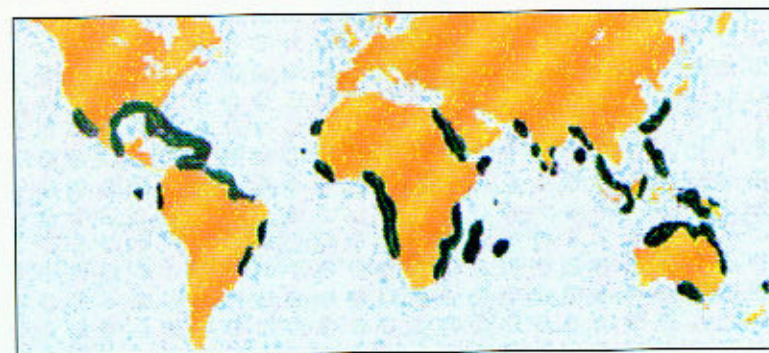
harbours other plant and animal species. These are highly productive but extremely sensitive and fragile areas.

The Greek explorer Nearchus first mentioned the mangrove type of vegetation as far back as in 325 B.C. Theophrastus, the Father of Botany, also described mangroves saying, "The trees are all washed by the sea up to their middle and they are held up by their roots like a polyp". Pliny in his *Historia Naturalis* mentioned the mangroves present in Red Sea. An account of the Indian Ocean mangroves was provided by Van Rhlede in his *Hortus Malabaricus*.

However, most of these, and later, descriptions were taxonomical in nature. Though the unique growth characters and the adaptability of mangrove organisms were recognized a long time back, details of functional relationships began to be worked out only in the last few decades. It is likely that many other explorers and naturalists were familiar with the mangroves, but avoided them because of their unwholesome reputation. This is likely to have been the result of the persistent, if ill-conceived notion that mangrove forests have a filthy smell, squishy and oozing mud and harbored unpleasant animals such as crocodiles.

It is believed that the earliest mangrove species originated in the Indo-Malayan region and even today, there are far more mangrove species present in this region than anywhere else. Apparently, these early mangrove species spread westward, borne by ocean currents, to India and East Africa, and eastward to the Americas, arriving in Central and South America during the upper Cretaceous period and lower Miocene epoch, between 66 and 23 million years ago. During that time, mangroves spread throughout the Caribbean Sea across an open seaway which once existed where Panama lies today. Later, sea currents may have carried mangrove seeds to the

western coast of Africa and as far south as New Zealand. This might explain why the mangroves of West Africa and the Americas contain fewer, but similar colonizing species, whereas those of Asia, India, and East Africa contain a much fuller range of mangrove species.



Mangroves Distribution in the World

It is very interesting to note that mangroves are not absolutely and dedicatedly salt-loving (obligate halophytes, as scientists call such salt-lovers) but are also capable of growing in habitats irrigated by fresh water. However, under such circumstances, they exhibit growth considerably below their potential. It is apparent that the adaptation to salinity gradients definitely influences the distribution of mangrove plants within and between estuaries.

"Zonation" often characterizes mangrove forests. Certain tree species occupy particular areas, or niches, within the ecosystem. Some mangrove species occur close to shore, fringing islands and sheltered bays; others are found further inland, in estuaries influenced by tidal action.

The distribution of mangroves clearly establishes the existence of two groups of mangroves. The first group of

mangroves exhibit broad tolerances against salinities that may even be two or three times that of sea water. The other group is restricted to salinities less than sea water. Adjusting to, and coping with the inherently inimical nature of the surroundings, nature has bestowed some astounding biological characteristics on these plants.

Mangrove species are hardy. They need to be so in order to be able to survive inundation by salt water twice a day. They also have to thrive in "soil" which is unstable and poor in oxygen (anaerobic). In addition, they also have to deal with swollen rivers carrying silt during the wet season, as well as violent storms that hit the coasts. Such qualities deserve a closer look as they hold the keys to understanding the tricks of survival.

Apart from addressing scientific curiosity, there are inherent advantages too if one understands the mangrove ecosystems. Experience has proved that the presence of mangrove ecosystems on the coastline can save lives and property during natural hazards such as cyclones, storm surges and erosion. Besides, these ecosystems are economically important. They are breeding, feeding and nursery grounds for many estuarine and marine organisms. Hence, these areas are used for captive and culture fisheries. The ecosystem has a very large unexplored potential for natural products useful for medicinal purposes and also for salt production, apiculture, fuel and fodder, etc and therefore merit study.

It is fortuitous that interest in mangroves has been triggered. It comes not a day too soon because anthropological pressures are emerging as enemies of the ecosystem. Expansion of industrial areas along the coastlines and discharge of domestic and industrial sewage are polluting these areas. A close look at the mangroves is imperative if conservation efforts are to bear fruit.



Distribution of Mangroves

The single basic climatic factor governing the geographical distribution of mangroves is probably air temperature. Virtually all mangroves can be found at low latitudes, where the environment is warm and humid. Mangrove vegetation occurs in 112 countries and territories, mostly in the tropical and subtropical regions of the world. Their distribution is largely restricted to the southern hemisphere of the world, with some exceptions such as the northern limits of Japan and Bermuda.

Throughout the world there are about 50 species that belong to 16 different families but all of which are considered as mangroves. True mangroves are red mangrove (*Rhizophora* spp.), black mangrove (*Bruguiera* spp.), and white mangroves (*Avicennia* spp.). The number and distribution of mangrove species present interesting bio-geographical problems and one would do well to begin by taking a close look at the four broad types of mangroves that exist around the world.

(i) Red mangroves are highly salt-tolerant plant groups living very close to sea water. They, like all mangroves, have

characteristic modified roots, called prop roots that grow from the lower part of a stem or trunk down to the ground, providing extra support. The prop roots allow them to live on anaerobic substrate, provide gas exchange facilities, anchoring system, and absorbing ability.



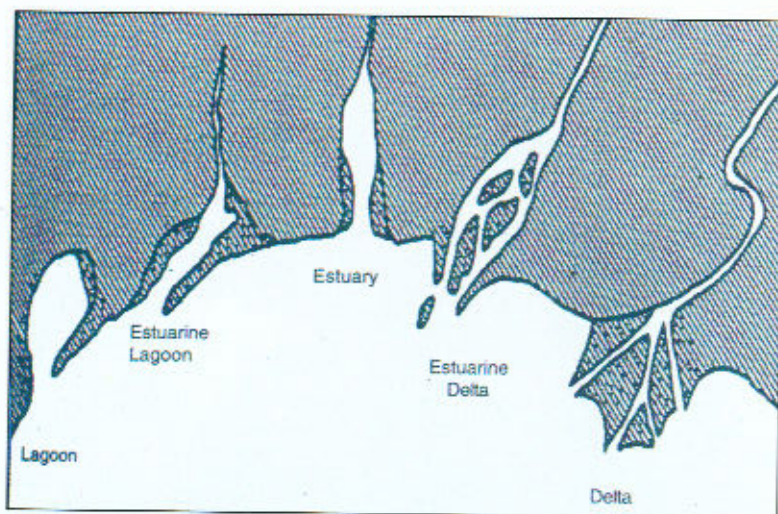
View of Pichavaram Mangroves

(ii) Black mangroves are moderately salt-tolerant. The wood of these trees is dark-brown to nearly black. These trees have the special breathing roots characteristically seen in plants whose roots are present in waterlogged soils. The special "breathing roots" emerge out of the soil. Breathing roots have special air channels (lenticels) for gas exchange and air enters at zones called pneumathodes.

(iii) White mangrove plant groups are so called because of their smooth white bark. The white mangrove is easily differentiated from other mangrove species by its leaves and



Stilt Roots of Rhizophora



Tropical coastal settings in which mangroves thrive (from Kjerfve, 1990)

root system. The leaves are rounded at the base and the tip and are smooth underneath.

(iv) Buttonwood mangrove is a shrubby mangrove tree that is usually low branching and multi-trunked. Its name refers to the red-brown, cone-like fruits that it bears.

Mangroves in India

India has a total area of 4,482 square km under mangroves. About 59 per cent are found along the east coast (Bay of Bengal), 23 per cent on the west coast (Arabian Sea) and the remaining 18 per cent on the Bay Islands (Andaman & Nicobar Islands in the Bay of Bengal).

There are three major types of coastal settings in which Indian mangroves exist as deltaic, backwater-estuarine and insular categories.

The deltaic mangroves occur along the east coast (Bay of Bengal) where the mighty rivers (Ganga, Brahmaputra,

Mahanadi, Krishna, Godavari and Cauvery) make the deltas. The backwater-estuarine type of mangroves that exists in the west coast (Arabian Sea) is characterized by typical funnel-shaped estuaries of major rivers (Indus, Narmada, Tapi with delta formation almost absent) or backwaters, creeks, and neritic inlets. The insular mangroves are present in the Bay



Breathing Roots

Islands, where many tidal estuaries, small rivers, islets, and lagoons support a rich mangrove flora.

The geomorphic settings of the mangroves on the east coast of India are different from those of the west coast. The mangroves are large widespread on the east coast of India due to the nutrient-rich alluvial soil formed by the mighty rivers and a perennial supply of freshwater along the deltaic coasts. But, the deltas with alluvial deposits are almost absent on the west coast of India, and their place is taken by the funnel-shaped estuaries or backwaters. The east coast has a smooth and gradual slope which provides larger area for colonization

by mangroves, whereas the west coast has a steep and vertical slope. The coastal zone of the Indian mainland and Andaman and Nicobar Islands sustain extensive and diverse mangrove forests. The west coast lacks major west-flowing rivers. The mangroves of the west coast of India are small in size and less diverse too. The environmental setting of the mangroves on



Vivipary (Baby Plant attached with Mother Plant)

the east coast of India differs widely from north to south as well.

Mangrove World Record

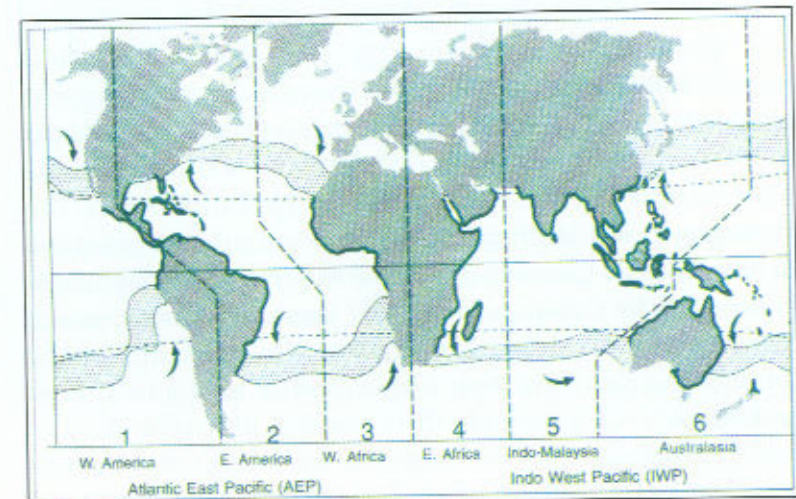
India boasts of several well-known mangrove ecosystems. Sundarbans is the largest mangrove forest in the world. It is shared by both India and Bangladesh. The Indian part of the Sundarbans is located in the western part of the Ganges – Brahmaputra Delta. Both the rivers are snow-fed and have a network of large distributaries and rivulets through which fresh water is supplied to the Sundarbans mangroves. Because of

**Table: Areal Coverage of Mangrove Forest
(from Spalding, 1997)**

Region	Area in sq km (% of total area)
South and Southeast Asia	75,170 (41.4%)
The Americas	49,096 (27.1%)
West Africa	27,995 (15.4%)
Australasia	18,788 (10.4%)
East Africa and Middle East	10,348 (5.7%)

this, the salinity of the water, both within the mangrove forest as well as near the sea, is lower than that of the surrounding sea water even during the summer months.

The Mahanadi mangrove ecosystem (Orissa coast) is located in the combined delta formed by the rivers Mahanadi, Brahmini and Baitarani. Thus this delta receives fresh water from three rivers. This ecosystem is rich in species diversity and plants here are dense and tall like those in the Sundarbans.



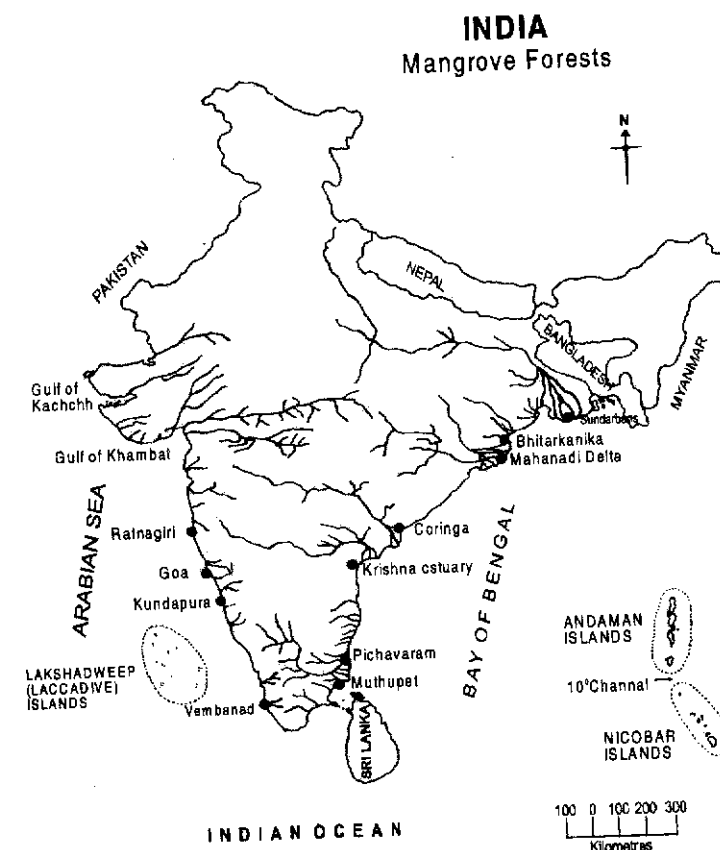
Global distribution of mangroves in six geographic regions (from Duke, 1992)

Table: Estimated Mangrove Coverage in 16 Countries having the Largest Mangrove Areas (from ITTO/ISME, 1993)

Country	Mangroves (x1000 ha)	Global Percentage
Indonesia	4250	30
Brazil	1376	10
Australia	1150	8
Nigeria	970	7
Malaysia	641	5
Bangladesh	611	4
Myanmar	570	4
Vietnam	540	4
Cuba	530	4
Mexico	525	4
Senegal	440	3
India	360	3
Colombia	358	3
Cameroon	350	2
Madagascar	327	2
China	75.69	0.5

The Godavari mangrove ecosystem (Andhra Pradesh) is located in the delta created by the river Godavari. This forest is actually a river-dominated mangrove wetland. The Krishna delta is home to mangroves that are watered by the distributaries of the River Krishna. In Tamil Nadu, the Pichavaram and Muthupet mangroves are present in a large delta called the Cauvery delta. The Pichavaram mangrove is located in the Coleroon delta. All these different types of mangrove forests in India have variations in environmental settings and also have their own influence on the local flora and fauna.

Naturally resilient, mangrove forests have withstood natural calamities and changing tides for millennia. But they



Important locations of mangroves (indicated as •) in different maritime states of India.

are now under threat and facing destruction because of encroachments leading to habitat destruction. The situation is compounded by the lack of awareness about these splendid and irreplaceable ecosystems.

Kindling an interest in the minds of the people and sustaining the awareness created about the importance of these ecosystems would definitely be steps forward in helping save these plants.

Table: State-wise and District-wise Cover of Mangrove Forests in India (from Forest Survey of India, 1999, 2001; Values in parenthesis are the latest figures reported by FSI, 2001)

S. No.	State	Districtwise area (km ²)	Statewise area (km ²)	Total Area (%)	
1	East coast: West Bengal	Medinapur 24 Parganas North 24 Parganas South	3 29 2093	2.125 (2081)	43.63 (46.31)
2.	Orissa	Baleshwar Bhadrak Jagatsinghpur Kendrapara	3 18 10 184	215 (219)	4.40 (4.89)
3.	Andhra Pradesh	Godavari Krishna Guntur	241 104 52	397 (333)	8.15 (7.43)
4.	Tamil Nadu & Pondicherry	South Arcot Thanjavur Pudukottai	9 12	21 (24)	0.40 (0.55)
5.	Bay Island: (Andaman & Nicobar)	Andaman Nicobar	929 37	966 (789)	19.83 (17.6)
6.	Gujarat	Bharuch Bhavnagar Jamnagar Kachchh Surat Unagarh Valsad	6 25 140 854 4 1 1	1031 (911)	21.17 (20.33)
7.	Maharashtra	Mumbai city Mumbai Thane Raigarh Ratnagiri	2 32 24 38 12	108 (118)	2.22 (2.63)
8.	Goa	Goa	5	5 (5)	0.10 (0.11)
9.	Karnataka	Dakshina Kannada Uttara Kannada	2 1	3 (2)	0.06 (0.05)
10.	Kerala			Sparse	-
	Total			4,871 (4,482)	100.00



Biology of Mangroves

It is practically inconceivable for the casual observer to comprehend just how these plants survive on their chosen habitat that is literally the interface between land and sea. If a garden plant is watered with sea water, the plant will wither and die as the salt will extract water from the plant and dehydrate it. Contrast this situation with that of a mangrove tree that seems to thrive under such potentially hostile conditions. But a closer look reveals that, though the plant is growing in salt water, it is physiologically 'dry' because of the non availability of sweet water. However, if a mangrove plant seems to thrive in the saline habitat with fluctuating salinities due to tides, desiccation and weather exacerbating the situation, it is because of certain unique features.

Mangrove plants are specially adapted to enable them to survive in the harsh environment. Not only do these plants have morphological features that allow them to remain strongly anchored to the ground, but they are also equipped with special breathing roots to obtain adequate oxygen for respiration. They also have physiological systems to cope with salt and desiccation stress.

Without these natural adaptations the mangroves would have failed to colonize their harsh habitats. Even with such adaptations in place, mangroves experience many problems stemming from their growth in or near sea water. But it is worthwhile to take a closer look at the special adaptations of mangrove plants that allow them to overcome the harshness of their environment.



Salt Precipitated on the Leaves

Dealing with extra salt

Mangrove plants are a diverse group that has learnt to exploit the intertidal zone because they have developed physiological adaptations to overcome the problems they encountered in their habitat. To deal with salt, all mangrove trees exclude some salt at the root level, and all can tolerate more salt in their tissues than what "normal" plants can. Mangroves can tolerate salt, often in quantities that would kill other plants. Some mangrove plants have an effective ultrafiltration system at the root level to exclude salt. It is said that the mangrove root system is so

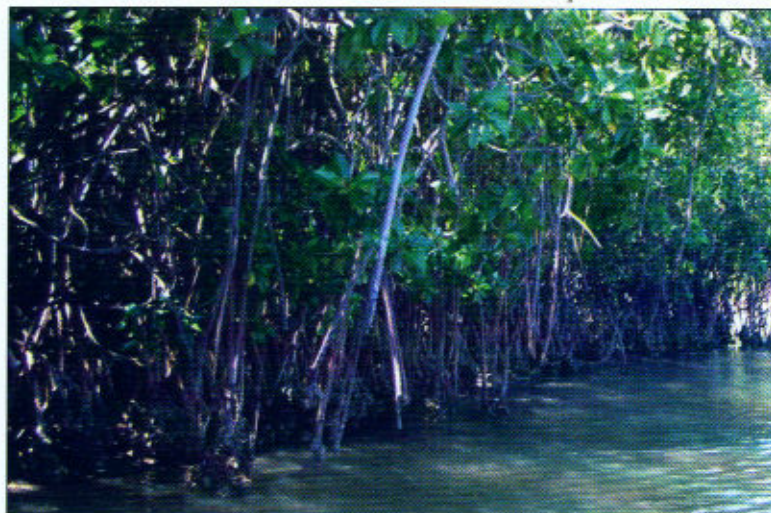
effective in filtering out salt that a thirsty traveler could drink fresh water from a cut root, though the tree itself stands in saline soil. Any salt that gets through into the plant tissues, even after such filtration, is stored in old leaves which are later shed thus ridding the plant of undesirable salt loads. In some species, the excess salt is sequestered in vacuoles prior to disposal. Restricting the salt to vacuoles keeps it from interfering with cellular activities. There are some mangrove plants that "cry" i.e., shed droplets of salty water. These salty teardrops are exuded through specialized salt glands.

A few mangrove plants can tolerate high levels of salt in their tissues and their sap can be up to one-tenth as salty as sea water. They then secrete the excess salt through special cells on their leaves. The mangrove plant, *Avicennia*, does this best and it is often the only tree to survive in hot, salt-rich regions. Some other mangrove associates also do this quite well, for example, Sea Holly (*Acanthus* sp.). This ability is paramount for survival because, although mangrove trees are adapted to grow in salt water, they require regular flushing with freshwater. They will die if immersed in saltwater all the time.

Finding extra support

Mangroves grow in unstable grounds. Their truly remarkable roots, not only provide support in unstable soils, but also withstand currents and storms, and breathe air in the bargain. To avoid suffocation in the oxygen-poor mud, mangrove trees snorkel for air. They have developed aerial or air-breathing roots to take in atmospheric air. All aerial roots have on their surface, special tiny pores (lenticels) to take in air from the atmosphere. Only air can get through the lenticels, not water or salts. All aerial roots also contain large air spaces (aerenchyma). These not only transport air, but also provide a reservoir of air during high tide when the aerial roots may be

submerged. The functions of aerial roots are to absorb air and also to provide structural support to help enable the plants withstand wind velocity. Most mangrove trees lack heartwood. Instead they have narrow vessels that are densely and evenly distributed throughout the wood. Thus, they are able to withstand damage to the bark and outer trunk.



Submerged Roots of Rhizophora

Remarkable roots

Aerial roots can take on different forms. *Avicennia* develops shallow cable-like roots which spread out from the trunk. Along these cable roots emerge short pencil-like roots called pneumatophores (meaning “air carrier” in Greek). It is amazing to see that a 3-metre tall *Avicennia* can have 10,000 pneumatophores. *Sonneratia* also produces pneumatophores, but these are cone-like in shape. *Bruguiera* sends out knee roots that emerge from the ground then loop back. These roots resemble the human knee in shape –hence the name. *Rhizophora* send out roots from its trunk and branches. These arch down to the ground for extra support and air absorption.

Tough toddlers

If it is hard for adult trees to cope with their environment, it is even harder for tender seedlings which are usually dispersed by seawater. Thus many mangrove trees have special adaptations to give their offspring the best chance of survival in their harsh habitat. Many provide their seedlings with a good store of food and floatation devices. In some, the fruit does not fall away when it ripens. Instead, the seed within the fruit starts to germinate while it is still on the mother tree, and the mother tree channels nutrients to the growing seedling (vivipary).



Diversified flora of mangroves

Vivipary

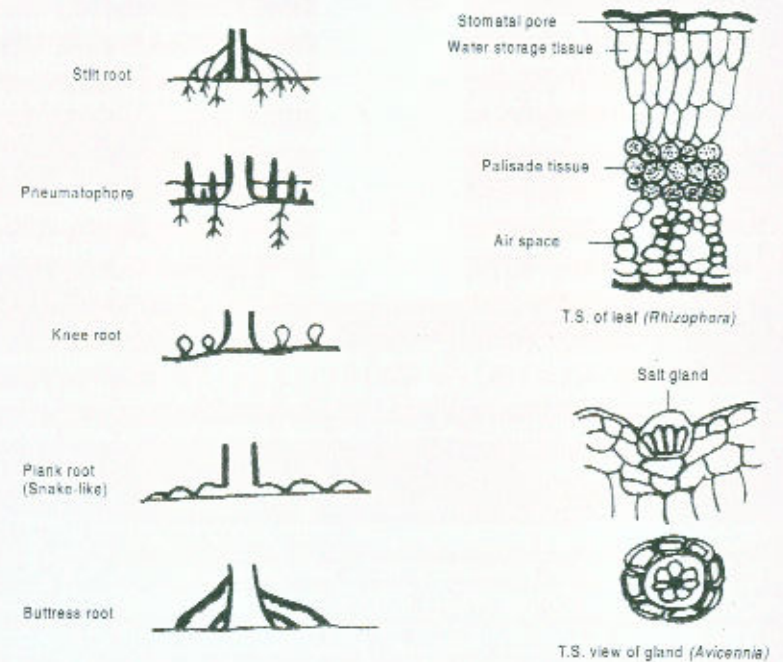
In some plants, like *Avicennia* the growing seed does not break through the fruit wall while the seed is on the mother plant. It does so only when the fruit falls off (cryptovivipary). In others, the growing seedling breaks through the fruit wall to form a stem (called a hypocotyl), sometimes even roots (as in *Rhizophora*,

Bruguiera). The entire seedling is then called a propagule (potential plant). In some trees, the seedlings fall off in the water only at high tide. (*Aegiceras*). This almost guarantees that the waves will carry them great distances, thus aiding dispersion.



Pneumatophore of Xylocarpus

When the propagule finally falls, at first it floats horizontally, and drifts with the tide. It can survive for long periods at sea. The tip is water absorbent while the top end is water repellent. After some weeks, the tip gradually absorbs water and the seedling floats vertically and starts to sprout its first leaf from the top, and roots from the bottom. When it hits soil, it hauls itself upright by growing more roots, and then sprouts more leaves. The long stem is a short-cut to sunlight



Diagrammatic representation of some of the adaptations in the root systems and in leaves of mangroves

and oxygen as seedlings are often completely submerged at high tide. Amazingly, young seedlings can survive being completely underwater until they are big enough to grow aerial roots, at about 1-2 years. Meanwhile, they depend on stores of air in the air spaces (aerenchyma) in their stems.

Water, water everywhere, not a drop to drink

Freshwater is as precious to a mangrove tree as it is to a desert plant. Mangrove plants have to expend energy to get rid of the salt from every drop of the water they use. Thus mangroves have many water conserving features that they share with plants that grow in the desert. To a casual observer this may

appear to be a paradox because the mangroves appear to thrive in what is obviously a very water-rich area. But physiologist will point out that a salt water habitat is potentially every bit as dehydrating as a desert environment.

To minimize water loss through evaporation mangroves have thick waxy leaves. Hairy leaves that trap an insulating layer of air near the leaf surface is another adaptation.

They may also store water in succulent leaves. Mangroves also protect themselves with spiny or waxy leaves that deter herbivores. High levels of tannins and other toxins also serve the same purpose.

Mangrove Root Architecture

The alarming situation in which mangroves routinely find themselves is that they live in the most inundated of places, where their roots must come out of the soil to breathe. Usually roots grow inwards into the soil and away from sunlight. But mangroves produce roots which grow against the gravitation force and breaking out of the soil surface. Mangrove root systems are not deep because of poor aeration of the soil. Though the roots are not deep, these branch out extensively. Profuse branching ensures that more surface area is covered and the plant is securely anchored in the soil. The soil where the mangroves grow is very deficient in oxygen. To cope with this, mangroves have additional roots, which may be called adaptational roots which adopts to low oxygen environment by increasing the oxygen absorption for the plant.

It is thus evident that mangroves are specialized plants that have evolved to adapt to their unique habitats. They are indeed blessed by Mother Nature to colonize and thrive in places that would defeat other less-adapted species.



Climatic Factors

The common conception about mangroves is that they are a community of peculiar plants growing along the coast on stinking black mud. Of course this idea is incorrect since mangroves have been known to grow on sand, reef flat and even on rocky substrates. The nature of soil is the most important factor controlling the growth and distribution of mangroves. The soil structure and salinity may exhibit large variations which in turn may reflect in the variations seen in the many mangrove species around the world.

The Andaman and Nicobar Islands have volcanic soil. But that has not deterred the mangrove vegetation from colonizing the land. Pichavaram mangrove grows on soil that is made up of fine and coarse silt with clay, and sometimes, fine sand and coarse sand. But in the Cochin backwaters in Kerala, the soil is dark and acidic in nature. Here too the mangroves seem to thrive with little or no apparent difficulty. The Sundarbans forests have alluvial soil whereas the Gujarat Coast has fine silt and clay mixed with soft sand stone. In both areas large areas of are under mangrove vegetation.

The nature of the soil may differ from place to place but mangrove growth mostly depends on the salinity, nutrient content, permeability and drainage of the soils. Atmospheric temperature that favours mangrove growth usually ranges between 20°C and 35°C. Land and sea air flow makes the temperature fluctuation more dynamic and ever-changing in character. Rainfall is the most important factor to determine the salt concentration in the medium which supports the life of mangroves. Rainwater dilutes the salt concentration in the sea waters around mangrove roots. No wonder, mangroves usually develop best in the region, experiencing abundant rainfall that is also evenly distributed throughout the year.

Rainwater serves another, equally important though perhaps less obvious, purpose. Successive tidal floods, in areas where mangroves grow, bring in salt water to inundate the land surface. Subsequent evaporation results in the formation of thick salt crust on the soil surface. This checks the regeneration and growth of the mangroves. But rain water washes out the surface salt and makes the land suitable for the growth of mangroves. The soil structure and soil salinity are the controlling agents of distribution of mangroves. Tidal fluctuations also play a major role in the ecology of mangrove habitats.

Man does not appear to have much of a role to play in controlling the tides but the changing pattern of rainfall associated with global warming and other large scale climate disruptions, as result of human activity, may adversely affect the finely-tuned balance of nature. The results will not be grave just for the vegetation concerned. Man cannot hope to escape the consequences either.



Flora and Fauna

Mangrove forests that were once considered wastelands or useless swamps or even unproductive, transitional forests are now viewed as highly productive, ecologically important areas. The land available to the mangrove forests lies in the intertidal zones, and the principal habitats to terrestrial flora is restricted mostly to trees. But it is incorrect to surmise that mangrove forests support little habitat diversity and only a few species. The truth is that mangroves support diverse flora and fauna. This habitat provides homes and food for other plant groups also.

Mangrove forests not only include tree species but also include microbes, fungi, and algae. The functioning of the mangrove environment mainly relies on the phyto-planktons and microalgal communities present in the habitat. The diversity of macroalgal flora in mangrove habitats provides food for a number of invertebrates and fish species. Algal diversity is quite high in the mangrove environment. Their abundance and diversity are largely determined by the physico-chemical properties of the mangrove environment. Algal distribution in mangrove habitats exhibit zonation patterns which mainly depend on the variation in salinity,

Table: Summary of the Total Number of Faunal Species Reportedly Occurring from Mangrove Habitats Along the East and West Coasts of India, and from the Andaman and Nicobar Islands (from Kathiresan, 2000a)

Faunal group	No. of faunal species			
	East Coast	A&N Islands	West Coast	Total
Prawns and lobsters	36	17	29	55
Crabs	87	56	27	134
Insects	367	339	10	705
Mollusks	181	113	81	302
Other Invertebrates	574	74	181	740
Fish parasites	7	0	0	7
Finfishes	330	249	124	543
Amphibians	7	5	0	11
Reptiles	77	7	3	82
Birds	316	53	257	419
Mammals	61	8	3	68

temperature, tidal inundation, wave action, wetting frequency and light intensity.

Sea grasses are plants intimately associated with mangroves. It is very interesting to note that the growth and biomass of sea grasses are higher in the vicinity of mangroves. Scientific studies have proved that mangrove and sea grasses show many parallel functions in the habitats. Salt marsh plants often replace mangroves in certain coastal part of the world. But even these are not able to survive in areas of high salinities and fast sediment accretion, and then, in such areas, these are replaced by mangroves.

Diversified flora of mangroves

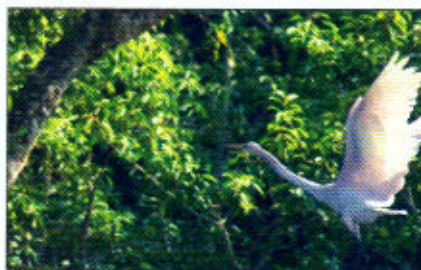
Mangroves belong to many different families which may not be closely related in a phylogenetic sense but have, in common, a number of special characteristics. Such characteristics include presence of pneumatophores and viviparous nature. Earlier, *Rhizophora* species alone was considered as the representative of mangrove plants. However, after thorough exploration of the habitat, the true picture of the diversification mangrove plants is now clear. But it is very difficult to find all the species of mangroves in one place on Earth. The most important genera of mangroves are *Acanthus*, *Acrosticum*, *Aegialities*, *Aegiceras*, *Avicennia*, *Bruguiera*, *Camptostemon*, *Ceriops*, *Cynometra*, *Dolichandrone*, *Excoecaria*, *Heritiera*, *Kandelia*, *Lumnitzera*, *Nypa*, *Osbornia*, *Pemphis*, *Rhizophora*, *Scyphiphora*, *Sonneratia* and *Xylocarpus*. Genera such as *Laguncularia*, *Mora* and *Tabebuia* are present, very rarely, in some parts of mangroves of the world.

Diversity of Mangrove flora in India:

The Indian mangroves are not uniformly distributed throughout the Indian coast. Species diversity is higher on the East coast as compared to the West coast. The mangrove forests of the Sundarbans are dominated mostly by the woody species. The Sundarbans mangrove vegetation includes two palm species, namely *Nypa fruticans* and *Phoenix paludosa*. This natural forest is dominated by *Sonneratia apetala*, *Ceriops decandra* and *Avicennia marina*. The mangrove forests of Andaman and Nicobar Islands are very rich in species diversity and species composition. The mangroves of the Andaman Islands are dominated by *Rhizophora* species. The mangrove forests here are almost exclusively made up by this species. Scientists call such forests monogeneric which means made up of one genus only. The mangrove vegetation on the Indian mainland exhibits zonal pattern of distribution.

Mangrove- associated Fauna

Faunal associations are usually associated with tidal expanse, and tidal amplitude in respect of shore animals. In case of mangrove associated fauna, the distribution is also related horizontally (from the mangroves towards the sea) as well as vertically from the tree canopy to the lower parts of the plants. The wild life that thrives in mangrove forests is quite diverse and interesting.



Picture showing Migratory Bird Flying in Mangroves

The majority of mangrove fauna is composed of invertebrates such as arachnids (spiders and relatives) and insects. Communities belonging to porifera, cnidaria, bryozoa, polychaeta, mollusca and arthropoda live on the roots. Mangrove crab diversity is very high with an estimated 275 species from six families of true crabs being associated with the mangrove ecosystems of the world. These true-crabs occupy



Picture showing Migratory Bird nesting in Mangroves

the intertidal zone of mangrove ecosystem. As many as 35 species of crabs have been recorded from the Andaman and Nicobar Islands. The diversity of crabs in Sundarbans is comparatively higher, with nearly 52 species being native to the area. Faunal components that are distributed towards landward side of the mangroves are large crabs belonging to *Cardiosoma carnifex*, medium crabs such as *Sesarma (Chiromantes) bidens*, *Sesarma*

Table: Summary of the Total Numbers of Floral and Faunal Species occurring in Mangrove Ecosystems of India (from Kathiresan, 2000a)

S.N.	Group	No. of Species
	Floral groups	
1.	Mangroves	71
2.	Saltmarsh vegetarian	12
3.	Seagrass vegetarian	11
4.	Marine algae (Phytoplankton + seaweeds)	557
5.	Bacteria	69
6.	Fungi	102
7.	Actinomycetes	23
8.	Lichens	32
	Faunal groups	
9.	Prawns and lobsters	55
10.	Crabs	134
11.	Insects	705
12.	Mollusks	302
13.	Other Invertebrates	740
14.	Fish parasites	7
15.	Finfishes	543
16.	Amphibians	11
17.	Reptiles	82
18.	Birds	419
19.	Mammals	68
	Total number of species	3943

longipes; small crabs such as *Uca lactel*, *Uca (Deltuca) dusumieri*, *Uca (Thalassuca) vocans*.

Among the vertebrates, amphibian diversity is comparatively low and limited to freshwater species venturing

into the area occasionally. Frogs such as *Rana cyanophlictis*, *R. tigerina*, *R. hexadactyla*, inhabit the Sunderbans mangroves. Reptiles that inhabit the mangroves include crocodile, snakes and lizards. Salt water crocodile (*Crocodylus porosus*) is found on the Andaman and Nicobar islands, and also, occasionally



Monkey in Mangrove

in the Sunderbans. The Andaman water monitor lizard (*Varanus*) is common during the breeding season of the crocodiles, as it is fond of lifting crocodile eggs. The Dog-faced water snake (*Cerberus rhynchops*) is

frequently found deep inside mangrove forests. Lizards such as *Gonioccephalus* and *Calotes versicolor* are common in mangrove forests. Turtles and terrapins are found in some mangrove forests of the world.

Birds use mangroves as the roosting and feeding sites. Mangrove forests are permanent residences of several land birds, wading birds and aquatic birds. For the migrant birds, mangrove forests are stopover sites. It is common to see the Grey herons (*Ardeola cinera*), Night herons (*Nycticorax nycticorax*), Egrets (*Egretta intermedia* and *Egretta garzetta*) in Sundarban mangroves. Six species of kingfishers have been recorded from the Sunderbans, and eight species from the Andaman and Nicobar Islands. The commonly encountered kingfishers are: *Alcedo atthis*, *Halcyon smirnsensis*, *H. pileata*, *H. chloris*, *H. coromanda*, *Ceryle rudis*, *Pelargopsis amauropera*, and *P. capensis*. In addition to birds, the mangrove canopy harbors many species of insects, reptiles, and mammals.

Many marine fish spend their lives restricted to the mangrove habitat. This ecosystem provides two important things for the juvenile fish: food and shelter. Mangroves form a crucial link in the life history of most of the commercially important reef organisms. They are incredibly important for maintaining fish diversity and abundance in the tropics.



Mangroves roots protected habitat for Larval & juvenile fishes

The roots of mangroves provide a protected habitat for larvae and early juveniles of marine fishes. Fish diversity is very high in the mangroves. It has been postulated that mangroves are nursery grounds for many commercially important fish species. Mangroves also play a special role as nursery habitat for juvenile fish. The juvenile stages of adults that occur in other habitats may migrate to mangroves.

Positive correlations have been drawn between fish population abundance and mangroves. Fish living in the mangroves must adjust to temporal and spatial variability in

physical and chemical conditions and some species possess specific adaptations to deal with this. The widely distributed hermaphrodite killifish (*Rivulus marmoratus*) is well adapted to mangrove habitats.

Among larger animals seen here are monkeys, flying foxes, otters, deer, fishing cats, snakes, wild pigs and tigers (Royal Bengal Tigers). Mammals present in the mangroves include monkeys (*Macaca fascicularis umbros* in the Andamans and *Macaca mulatta* in the Sunderbans). It does not therefore needless to say that any threat to the mangroves places all these species in danger too.



Mangrove Ecosystems

Mangroves provide a unique ecological environment for diverse communities of flora and fauna. This habitat contributes in a large way to the global carbon cycle. Many organisms utilize the mangroves in some way or the other, at least in some part of their life cycle. Mangroves play a crucial part in maintaining coastal tropical biodiversity. First and foremost, they act as a nursery for many species that live in and around coral reefs. The inter-weaving underwater roots in a mangrove forest create a multitude of niches where a great number of fish, crustaceans, and turtles find shelter and breed, safely out of reach of voracious predators found on the reef.

Mangrove forests, like many tidal wet lands, accumulate nutrients such as nitrogen, phosphorus, heavy metals, and trace elements that are deposited in estuarine waters from terrestrial sources, and thus act as nutrient “sinks” for these materials. Mangroves recycle carbon, nitrogen, and other elements extracted from dead and decomposing components turning these into dissolved, particulate and gaseous forms. The inflow and outflow of water from this habitat assists in the distribution of these materials to areas where other organisms may utilize it.

The major primary production in the mangrove ecosystem is courtesy of the trees. The detached parts of the mangrove plants are called 'litter fall'. These include leaves, stems, roots, flowers and fruits. Most of this enters the waters as litter fall. The seeds of *Avicennia germinans* and *Rhizophora* species account for 25 per cent of the total litter fall of the mangrove habitat. The litter fall is heaviest during summer. This is a typical trait exhibited by mangrove vegetation to reduce water loss by transpiration.

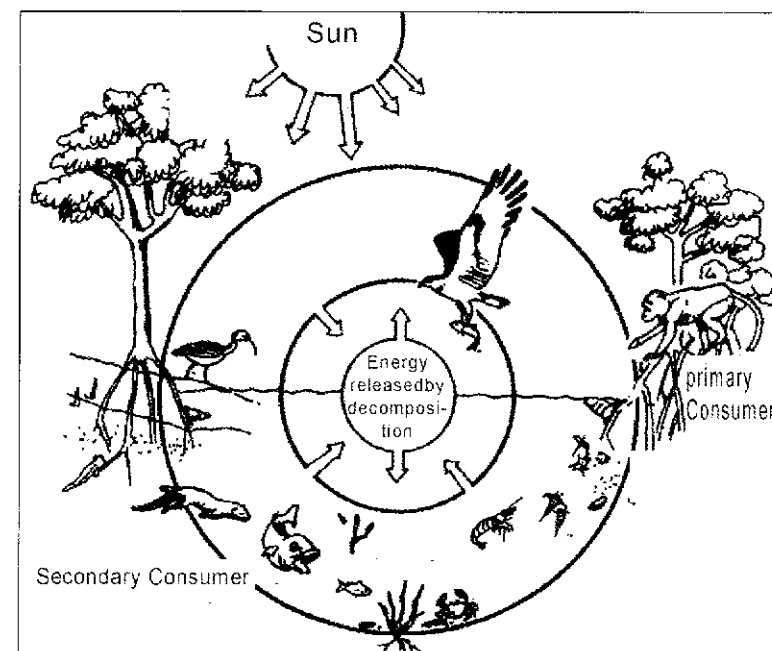
Microorganisms found in the soil decompose the fallen plant parts. During this process, nutrients are released which enrich the surrounding waters. The decomposed organic matter along with microbial biomass is known as detritus. This is an important product produced in the mangrove ecosystems. It is rich in protein and it serves as a nutritious food for a variety of organisms, which may also filter the detritus particles from the water column. Detritus-feeding fishes are preyed upon by larger carnivorous forms. The influx of nutrients generated by the mangroves supports other sensitive habitats like the coral reefs, seaweeds and sea grass beds.

The consequence of heavy litter fall followed by more freshwater input during rainy season is that there is an increase in the nutrient supply. The decomposition of litter fall produces detritus. Action of microbes on this detritus enhances its nutritive value for the juveniles of a variety of shrimps and fishes, which migrate into this environment looking for food. The volume of litter fall and production appears to depend on local condition, species composition, and productivity of the individual *mangal*.

Food cycle in Mangrove Ecosystems

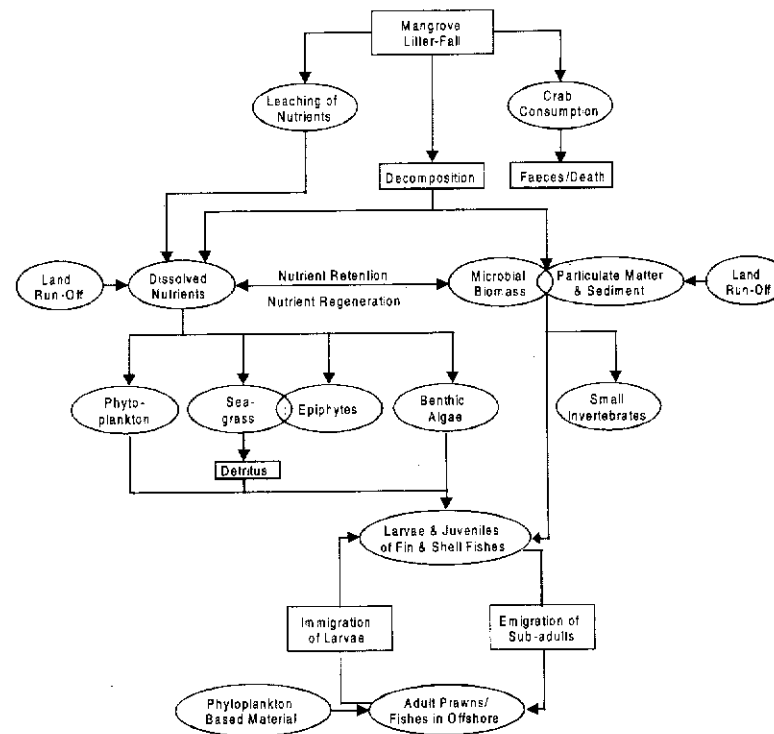
Flowering plants, phytoplankton and marine algae are responsible for primary productivity in the mangrove ecosystems. The faunal elements like zooplanktons are responsible for secondary productivity and benthic

communities of life forms are responsible for tertiary productivity. Bacteria and fungi acts as decomposers. There is a perfect sequential energy flow between the producers to decomposers and these cycles manifest naturally. The energy export and import are perfectly balanced. This confers stability to the mangrove ecosystem.



Food cycle in Mangrove Ecosystem

The mangrove forest is a rich source of nutrients. It supports large number of benthic organisms. This includes molluscs, crustaceans, echinoderms, flatworms or planarians, nematodes and larval forms of several other organisms. Since this habitat is rich in detritus food, it provides resources for detritivorous species of fishes, crabs, crustaceans and molluscs. In India alone, it is estimated that about 60% of coastal marine fish species is dependent on the mangrove habitat.



A diagrammatic scheme of the food web in a mangrove ecosystem (from Kathiresan & Bingham, 2001)

Mangrove forests are major feeding grounds for many life forms. These are effective nutrient recyclers, supporting the ecosystem and keeping it healthy. Acting as a buffer zone between land and sea, mangroves also help create the right conditions for coral reef growth by filtering sediments and pollutants that would otherwise choke or poison the coral. Were it not for mangroves, coral reefs would be even more stressed than they already are because of a variety of other pressures impacting on them. Mangroves perform protective function for the coastline, saving millions of dollars each year in coastal erosion damage.



Importance of Mangroves

The human community exploits the mangroves in many ways. Traditionally mangroves have been sustainably used for food production, medicines, fuel wood, and construction materials. Many indigenous coastal residences rely on mangroves to sustain their traditional cultures. Mangrove forests act as a buffer zone between the ocean and land, and naturally protect the shores from damage caused due to sea borne natural calamities. These protect the coastal land areas from siltation problems, preventing a great deal of property damage and sometimes even loss of human lives.

Coral reefs are believed to be the most biologically diverse marine ecosystem on earth. This ecosystem is a very delicately balanced system depending on abiotic and biotic factors present in the marine environment. The nearby mangroves are the nursery and breeding grounds for the teeming marine life forms found in and around coral reefs. The mangrove root system protects the reefs from terrestrial sedimentation and other forms of pollution. The reefs serve as wave breakers, helping to protect the mangroves from forceful wave impacts. Thus the mangrove and reefs coexist by helping each other.

Mangroves: Mother Nature's Refuge

Mangroves provide refuge to the vulnerable species that live in the area. They provide shade and safety too. Their roots provide a surface for all kinds of creatures from algae to shellfish to use as a haven. The tangle of roots provides hiding places, for young fishes and shrimps, from larger predators. The overhanging branches provide shade from the scorching



Mangrove roots - a micro habitat

Sun and also serve as resting places for creatures as diverse as Proboscis Monkeys to nesting sites for herons. The tiny crevices are homes to insects and other tiny creatures. Tree-climbing crabs and sea snails climb up their aerial roots at high tide to avoid aquatic predators.

Mangrove ecosystems are important for fish production. They serve as nursery and breeding grounds for many species of fish and shellfish. The Pichavaran mangrove ecosystem

alone nurtures 30 species of prawns, 30 species of crabs, 20 species mollusks, and 200 species of fish. It is widely believed that mangroves are like the roots of the sea.

If there are no mangrove forests along the coastline there will be, either no fish, or fewer fish.

Besides fish, the mangroves support variety of wildlife such as the Bengal tiger crocodiles, deer, pigs, snakes, fishing cats, insects and birds. Other important animals associated with the mangrove ecosystems are the dolphin (*Platanista gangetica*), mangrove monkey (*Macaca mullata*) and otter (*Lutra perspicillata*). The endangered Wild ass (*Asinus hemionus*) is frequently seen in the mangrove ecosystem of the Kutch region. Crab-eating macaques (*Macaca fascicularis*), langur (*Presbytis cristatus*), flying fox (*Pteropus vampyrus*), monitor lizards (*Varanus flubiscence*), wild boar (*Sus vitatus*) and a few species of snakes are also found in the mangrove forests.

The largest living reptile (up to 7 m in length) is the *Crocodylus porosus* and several albino strains of this animal are found in the Bhitarkanika Mangrove forests of Orissa. This place is also one of the chosen nesting sites of the Olive Ridley turtles. The Coringa mangroves have recorded a total number of 54 species, including 4 amphibians, 12 reptiles, 25 birds and 13 mammals. However, the estuarine crocodile (*C. porosus*) has disappeared from the Coringa mangrove forests. The mangrove vegetation along the creeks of the Gulf of Mannar is feeding grounds for marine turtles and dugongs (sea cows).

Source of Food

Leaves of the mangrove trees are eaten by many kinds of creatures. Monkey snack on the shoots and leaves; the small insects nibble on them. Fallen leaves are an important source of nutrients both within the mangrove habitat and outside it

when these are flushed out to the coral reefs. The leaves are rapidly broken up by crabs and other small creatures, and further broken down by micro-organisms, into useful minerals. There are even tiny moth larvae that feed on pneumatophores. Thus the mangroves represent Nature's bountiful cornucopia to many living creatures.

Natural water filters

Underwater, a huge number of filter-feeders fastened onto the tangle of roots. These represent a conglomerate of barnacles, sponges and shellfish. These filter feeders clean the water of nutrients and silt. As a result, clear water washes out into the sea, allowing the coral reef ecosystem to flourish.

Mangrove sediments have a high capacity for absorbing and holding heavy metals thereby preventing the spread of metal pollution in coastal areas. The sediments contain 90 per cent of Mn and Cu released and almost 100 per cent of Fe, Zn, Cr, Pb, Cd in the ecosystem. Of course, some species are better at the job than others.

Disturbances may cause the mangrove soil to lose its metal-binding capacity. The mangal then gradually shifts its site from a heavy metal sink to a source where the accumulation is relatively low.

Mangroves remove organic wastes from the water and trap soil particles. This process helps in making the water clean and nutrient-rich. This benefits other associated ecosystems. As result coral reefs, seaweeds, seagrass beds flourish.

It has been seen that where the mangroves were removed, the sediment became loose and there was increased siltation in associated ecosystems which were subsequently destroyed. Large-scale deforestation of mangroves in the Gulf of Katch

has increased the siltation rate considerably causing damage and mortality to the adjoining coral reefs. In the Cochin Backwaters, deforestation of mangroves is probably one of the causes leading to extensive growth of an aquatic weed, *Salvinia* sp., which almost covers the entire backwaters, during the monsoon months and thus affects the fisheries drastically. It is abundantly clear that the mangroves provide protection to other marine ecosystems.



Mangrove forest protect Marine Eco-system

Screening Solar UV-B Radiation

Mangroves possess mechanisms to deal with intense sunlight rays and solar UV-B radiation. For example, *Avicennia* species grow in a hot and dry area receiving plentiful sunlight. The species is well adapted to arid zones, and Rhizophoracean species show greater solar UV-B tolerance than do other mangrove species. The mangrove foliage produces flavonoids that serve as UV- screen compounds. This ability of the mangroves provides a measure of protection against the deleterious effects of UV-B radiation.

Reducing 'Green House Effects'

Mangroves can remove CO₂ from the atmosphere through photosynthesis. They fix greater amounts of CO₂ per unit area, than what the phytoplankton do in the tropical oceans. They are capable of accumulating and storing carbon in the soil in large quantities. The ability of *Rhizophora* forest to divert carbon below ground is remarkably high. In the natural scheme of things, mangroves provide great benefits to control global climate change by stabilizing atmospheric carbon.

Mangroves also respond well to high CO₂. Because the mangroves fix and store significant amounts of carbon, their loss may impact the global carbon budget. It has been estimated that a loss of about 35 per cent of the world's mangroves has resulted in a net loss of 3.8×10^{14} g C stored as mangrove biomass.

Natural Stabilizers

Mangroves roots prevent mud and sand from being washed away with the tide and river currents. Mangrove trees slowly regenerate the soil by penetrating and aerating it. As the mud builds up and soil conditions improve, other plants can take root. Mangrove trees also reduce the damage from violent storms by anchoring the soil with their roots. Tropical cyclones and storms are common in the Bay of Bengal. They thus more severely affect the South Indian Coast as compared to that of the Arabian Sea. These cyclones hit the coastline with tremendous speed and inundate the shores with strong tidal waves, destroying coastal life. However, mangroves like *Rhizophora* spp. seem to act as a protective shield against this natural calamity.

The protective role of mangroves was best demonstrated when the super-cyclone lashed the Orissa coast on 29 October

1999 with a wind speed of 310 km/hr. It played havoc largely in the areas devoid of mangroves. However, practically no damage occurred in regions with luxuriant mangrove growth. There are several other examples on record.

Maximum loss of life and property has been reported in the aftermath of storms in the Mahanadi Delta, where large-scale deforestation and reclamation of mangrove land for other purposes has taken place. Then again, the 1970 typhoon and the accompanying tidal waves that claimed about 3 lakh human lives in Bangladesh probably would not have wrecked such devastation if thousands of hectares of mangrove swamps had not been cleared and replaced with paddy fields for short-term economic gains.

The Kutch area of Gujarat, where mangrove trees were illegally cut bore the brunt of the cyclone in 1983 and paid a heavy toll in the form of lives. All of the "Ecoservices" that the mangroves provide free of charge, to the local communities, are of tremendous importance.

Unfortunately, although the hardy mangroves have withstood fierce storms and heavy winds for thousands of years, they are now being devastated by human activities. But perhaps, recent events have forced people to reevaluate their stance *vis a vis* mangroves. The destructive Tsunami that struck India in December 2004 failed to devastate the villages, where mangroves stood as a barrier to these killer waves. The lives and properties of thousands of people in coastal villages of Tamil Nadu and Andhra Pradesh were spared because the mangroves stood as a shield between the fury of the tsunami and the vulnerable villages in its path. This incident served as an eye-opener and has made the coastal villages take a vow to conserve the mangroves. These events prove beyond doubt that mangroves are the best shelter-belt against cyclones.

Controlling Floods

Mangrove systems also protect the coastline against floods caused by tidal waves or due to heavy rainfall associated with storms. The flood-related disaster in Bangladesh (1991) would certainly have minimized, had the 300 km² mangrove area not



Mangrove forest preventing coastal erosion

been cleared for shrimp farming and rice cultivation. The ability of mangroves to serve as an agent of flood control is due to their spread-out root system that has evolved as a response to growth in areas prone to tidal inundation. *

Additionally, mangroves prevent the entry of seawater inland and thus protect the underground water systems. Very often, sharp changes have been noticed in salt concentrations of groundwater at the interface between salt flats and mangroves. This suggests that the mangrove systems can modify the salinity of the groundwater by lowering it drastically.

Preventing Coastal Erosion

The mangroves systems minimize the action of waves and thus prevent coastal erosion. The reduction of waves increases with the density of vegetation and the depth of water.

There is no doubt that mangroves form 'live seawalls', and are very cost-effective as compared to the concrete seawalls and other structures for the prevention of coastal erosion.

Trapping Sediments

Mangroves trap sediments and thus act as sinks for suspended sediments. The mangrove trees catch sediments with their complex aerial root systems. In this way they function as land expanders. It is thought that the mangroves inhibit tidal flows, probably due to the frictional force generated because of their root systems. The soil particles are carried in suspension into mangrove forests by the incoming tide. Then, the soil particles are left behind in the swamps and within the root system by the outgoing tides. The particles settle in the forests during the low tide, probably when the turbulence is reduced and water velocity at low tide is too sluggish to carry the particles back to the sea. This high efficiency of trapping suspended sediment may be attributed to the numerous respiratory roots in *Avicennia* and to compactly arching stilt roots of *Rhizophora*. The density of mangrove species and their complexity of root systems thus constitute the most important factors, for determining the sedimentation process.

Medicinal Uses

Coastal communities living close to and interacting with mangroves have gained the unique cognitive understanding of medicinal values of the mangrove plants. They have identified some species of mangroves for use in the treatment of snake bite, skin diseases, dysentery, and urinary disorders

as well as for birth control and as blood purifiers. The fruits of *Acanthus ilicifolius* are used for the treatment of snake bite and also for the treatment of kidney stones. The resin of *Avicennia alba* is used along with water and given orally for birth control.

The leaves of *Avicennia officinalis* are boiled in water and the decoction is widely used by local fishermen to treat stomach and also urinary disorders. The alkaloid containing leaves of *Bruguiera cylindrica* is known for its tumour inhibiting effect. The latex of *Excoecaria agallocha*, though poisonous and can blind the eye, has been used by the local community as a good medicine to treat toothache. Sea Hibiscus, a commonly found shore tree, has leaves that possess coolant effect and is used for controlling fever. Traditional knowledge and folklore about the medicinal importance of mangroves are part of human heritage. Much of it will vanish and the rest may become useless if the mangroves themselves tread the path to extinction.



Threats to Mangroves

Nature has blessed India with the world's largest mangrove forest— the Sundarbans. However, extreme human interference is a threat that needs to be addressed because it is making the mangrove population shrink as their natural habitat faces encroachments.

Mangrove environments are dynamic and cyclical. But human interference is tilting the balance of this ecosystem towards high mortality rates by subjecting them to different types of chronic stressors that inhibit the regeneration capacity of mangroves. For example, Lenticels in the exposed portions of mangrove roots are highly susceptible to clogging by crude oil and other pollutants, attacks by parasites, and prolonged flooding from artificial dykes or causeways.

Mangrove forests have often been perceived as unproductive areas, and mangrove vegetation is cleared to make room for agricultural land, or for development of tourist attractions, or for shrimp aquaculture, and salt farms. The argument being that the latter are more “productive” in nature. A blind eye is turned to the fact that the great earnings of shrimp culture are short-lived. The real costs in terms of environmental

damage and social disruption are long-lasting and astronomical! During the last three decades, about forty percentages of the mangroves have been converted into agriculture or urban centres. The result is that more than 35% of the world's mangroves are already gone and the remaining is being cleared at a rate faster than at which tropical rain forests are being decimated.



Vegetation is cleared to make room for agricultural land

To compound the problem, dams and irrigation reduce the amount of water reaching mangrove forests which lead to increasing the salinity levels in the mangrove forest. Freshwater diversions can also lead to mangroves drying out. If salinity becomes too high, the mangroves cannot survive. In addition,

increased erosion due to land deforestation can massively increase the amount of sediment in rivers. Erosion and deposition cause changes in the tides and currents, which in turn, have great impact on mangroves.

Over fishing causes imbalance in world ocean ecology. The ecological imbalance in food chains causes alteration in mangrove fish communities.



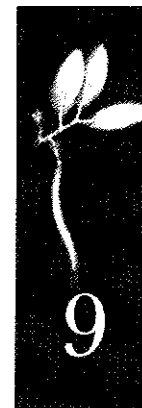
Mangroves are used as firewood

Coral reefs provide the first barrier against currents and strong waves. When they are destroyed, the stronger-than-normal waves and currents reaching the coast can undermine the fine sediment in which the mangroves grow. This can prevent seedlings from taking root and wash away nutrients essential for mangrove ecosystems. Fertilizers, pesticides, and other toxic man-made chemicals carried by river systems from sources upstream can kill animals living in mangrove forests. The surface run off of herbicides and defoliants applied to the crops pose the major pollution problems to mangroves.

Thousands upon thousands of hectares of lush mangroves forest are destroyed to make room for artificial shrimp ponds. Man-made problems arise mostly in the reclamation of mangrove lands for agriculture and prawn culture practices, tree felling for firewood, house and boat constructions and developmental activities. There is over-exploitation of fishery resources especially for the seeds of the tiger prawns. The gastropods and the bivalve species are exploited for lime preparation leading to a sharp fall in the biodiversity of these regions.

The mangroves are excellent feed for cattle. The buffaloes, goats and cows are set free in the mangrove forests during the summer months. They graze on *Avicennia* leaves and grasses. Local people also collect the leaves in large quantities to feed their cattle. It is believed that the buffaloes fed with *Avicennia* leaves produce more milk.

The mangroves are extensively used as firewood as they burn well. A ton of mangrove firewood is approximately equivalent to 2 to 5 tons of Indian coal and it burns with high heat without smoke. The villagers make their livelihood by cutting the wood from mangroves. Other threats arise due to salt manufacturing practices, replacement of mangroves by Casuarina, Cashew and other economic crops. Sea level rise is another major threat too. These unique coastal, tropical forests are now the most threatened habitats in the world.



Protecting and Conserving Mangroves

The importance of protecting mangroves was highlighted again after the recent Tsunami. Though legal restrictions have been imposed to prevent conversion of mangrove areas, mangrove forests are still under various types of pressures and immediate steps need to be taken to preserve mangroves for posterity.

Protecting the mangroves involves implementation of management plans based on ecological principles, which include pragmatic strategies for eco-development of the adjacent areas. A transboundary approach for mangrove conservation is highly desirable.

Restoration of Mangrove Ecosystems

Restoration of an ecosystem is the act of bringing it back nearly to its original conditions. It is also called rehabilitation, regeneration etc. Restoration of damaged mangrove ecosystems is high on the ecologist's agenda.

Mangroves protection should always have human-assisted restoration along with time bound management plan,

specifically for mangrove regeneration. Luckily, mangroves have natural regeneration capacity, so if proper protection is given, a depleted and degraded forest may regenerate over time. But it must be borne in mind that there is a limit to Nature's powers of regeneration and if the forests are decimated beyond this limit, regeneration is not possible.

The major goals of mangrove restoration are:

- (i) Conservation of rich biodiversity
- (ii) Sustainable utilization of fishery and forestry etc.
- (iii) Protection of coastal areas from the destructive aftermath of tidal waves/cyclones.

There are two types of activities in planting degraded mangrove areas: natural regeneration and artificial regeneration.

Natural regeneration: This involves the natural process of establishment of 'seeds' of mangroves. This method is advantageous because it produces the forest pattern, similar to the original forest and that it is cheaper and less disruptive to the habitat. However, the drawback is that it may not be successful in places where seeds are not readily available and in places where there is excessive weed growth, debris or where the soil is poor.

Artificial regeneration: This involves planting of seeds/seedlings. The seedlings may be transplanted to the new areas after being germinated in nurseries. This is a labour-intensive method. Vegetative propagation may also be resorted to. But this again, is a costly and difficult process. However, artificial regeneration does have its own advantages. It allows species composition, distribution, and density to be directly controlled. Genetically improved stocks may also be developed. Degraded

areas can be easily regenerated and objectives such as conservation, sustainable yield etc., can be manipulated to human advantage.

Restoration Parameters

Species selection is an important part of restoration, as are site selection, planting and monitoring. This is because the conservation of biodiversity calls for protection of native species, as well as enrichment of species diversity by introducing new species. Of course, the new species must be compatible with the existing ones so that the productivity of the forest ecosystem is enhanced. Mostly mangrove species selection is based on the species occurring naturally in the locality. Selection is also sometimes affected by the availability and maturity of planting material (tissue cultures) etc. Species are usually selected based on the cost of planting. Direct planting, immediately after collection does not require any storage. But when the planting material is sourced from far away, proper storage becomes essential to preserve viability. Species such as *Avicennia*, *Xylocarpus* and *Sonneratia* need to be raised in nurseries before plantation. This raises the cost of planting. Viviparous seedlings can be sown directly. This brings down the cost of planting. Usually seedlings are planted in the shade while mature trees do better in the sunlit canopy.

Site Selection

The site dictates what species will thrive on it. Physiological adaptations are not the same for all species. For example, tolerance to oxygen stress varies from species to species. Generally speaking, *Avicennia* species are more suitable for anoxic soil when compared to *Rhizophora*.

Zonation pattern is important while considering a species for regeneration purpose.

Table: Zonal Preference by Mangroves Species	
Tidal zone	Preferred species
High and mid-water levels	<i>Avicennia marina</i> , <i>Bruguiera cylindrica</i> , <i>B. gymnorrhiza</i> , <i>B. parviflora</i> , <i>B. sexangula</i> , <i>Ceriops decandra</i> , <i>C. tagal</i> , <i>Excoecaria agallocha</i> , <i>Scyphiphora Xylocarpus granatum</i> and <i>X. mekongensis</i>
Mid and low-water levels High-water levels	<i>Rhizophora</i> species, <i>Sonneratia alba</i> and <i>Aegiceras corniculatum</i> <i>Nypa fruticans</i> and <i>Lumnitzera</i> species

Rhizophora survives well at tidal heights corresponding to mean-water and lowest-water levels while *Avicennia* survives better at mid-water levels. Availability of soil

Table: Adaptability of Mangrove Species to Different Sites	
Mangrove species	Adaptability / preferable site
<i>Avicennia marina</i>	Relatively dry tidal lands, river banks or highly saline flats, arid zones
<i>Bruguiera gymnorrhiza</i>	With large freshwater supply
<i>Ceriops tagal</i>	High saline areas
<i>Nypa fruticans</i>	Site covered with grasses having lower level tidal inundation, low salinity
<i>Rhizophora apiculata</i>	Muddy sites of estuaries and mudflats
<i>Rhizophora mucronata</i>	Muddy sites of estuaries and mudflats
<i>Rhizophora stylosa</i>	Close to sea, it grows in areas of low tidal amplitude
<i>Sonneratia alba</i>	Close to sea, high saline areas
<i>Xylocarpus granatum</i>	Low saline sites, at low tidal amplitude area

nutrients is an important parameter but it is not an absolute one because the sites undergo tremendous changes in nutrient levels with respect to season etc. *Avicennia* species grow well in soil with high organic load if their

Table: Species Selection According to the Objective of Plantation	
Objective of planting	Candidate species
Natural regeneration	<i>Avicennia Marina</i> , <i>A. officinalis</i> , <i>Aegiceras corniculatum</i> , <i>Excoecaria agallocha</i> , <i>Acanthus ilicifolius</i>
Coastal protection against tidal waters, erosion and cyclones	<i>Rhizophora apiculata</i> , <i>R. mucronata</i> , <i>Sonneratia alba</i> , <i>Avicennia marina</i> , <i>A. officinalis</i> , <i>Heritiera fomes</i> , <i>Kandelia candel</i>
Protection of lagoons and estuaries	<i>Avicennia marina</i> , <i>A. alba</i> , <i>A. officinalis</i> , <i>Bruguiera cylindrica</i> , <i>Rhizophora apiculata</i> , <i>R. mucronata</i> , <i>R. stylosa</i> , <i>Sonneratia caseolaris</i> , <i>S. alba</i> , <i>Kandelia candel</i> , <i>Acanthus ilicifolius</i>
Dike protection along the sea and aquaculture farms	<i>Avicennia maria</i> , <i>A. alba</i> , <i>A. Officinalis</i> , <i>Ceriops tagal</i> , <i>Rhizophora apiculata</i> , <i>R. mucronata</i> , <i>R. stylosa</i> , <i>Sonneratia caseolaris</i> , <i>Bruguiera gymnorrhiza</i> , <i>Excoecaria agallocha</i>
Greening of barren coasts	<i>Avicennia officinalis</i> . <i>Ceriops tagal</i>
Restoration of mining areas	<i>Rhizophora</i> spp.
Introduction to new mudflats	<i>Rhizophora mucronata</i> , <i>R. apiculata</i> , <i>Avicennia marina</i> , <i>A. officinalis</i> , <i>Aegiceras corniculatum</i>
Harvest of forest products, timber, charcoal and firewood	<i>Sonneratia alba</i> , <i>S. apetala</i> , <i>Avicennia marina</i> , <i>A. officinalis</i> , <i>Rhizophora apiculata</i> , <i>R. mucronata</i> , <i>Ceriops tagal</i> , <i>Bruguiera gymnorrhiza</i> , <i>Kandelia candel</i> , <i>Heritiera fomes</i> , <i>Xylocarpus granatum</i>
Enhancement of fishery resources	<i>Avicennia</i> species, <i>Bruguiera</i> species

pneumatophores are healthy. *Rhizophora* can thrive even on old soils with deep mud and rich H_2S content. In general mangroves prefer soft, clay mud for good growth but not calcified or sandy areas.

Species Subtleties

Species such as *Avicennia* and *Sonneratia* are popular because they are swiftly growing species. *Avicennia marina* shows good resistance to high sunlight intensity and hot, dry conditions. It is well-adapted to arid zones. Species such as *Lumnitzera racemosa*, *L. littorea*, *Xylocarpus granatum* and *Ceriops tagal* also tolerate aridity well. But *Nypa fruticans*, *Heritiera fomes* and *Cynometra iripa*, to name a few, are not suitable for hot and dry areas. *Acanthus ilicifolius*, *Bruguiera gymnorhiza*, *B. cylindrical* and *Ceriops decandra* are tolerant of shade. Underplanting with suitable species in existing plantations can successfully combat insect infestations, meet geomorphic changes and provide for species succession.

Species are selected also keeping in mind their adaptability. For example, *Avicennia* and *Aegiceras* are salt-excretors while *Xylocarpus* is a salt accumulator.

Coastal Protection

In India, Vietnam, China and Bangladesh, coastal protection has greatly benefited from the introduction of *Sonneratia apetala*, *Avicennia officinalis* and *Rhizophora*. However, systematic studies on evaluating the suitable mangrove species for massive re-plantation programmes are yet to be undertaken. *Rhizophora* are quite tolerant to high wind speed and it has been noted that *Rhizophora mangle* were not greatly affected by hurricane though the larger *Laguncularia racemosa* were heavily damaged.

Extra Benefits of Mangrove Conservation

High methane levels are sometimes associated with anoxia in mangrove environments. Pneumatophore-bearing species release more methane via their leaves than those species that lack pneumatophores. Hence pneumatophore-bearing species appear to be best equipped to deal with high methane loads. *Rhizophora* species respond well to carbon-di-oxide. Therefore plantations of *Rhizophora* are beneficial in the context of global climate changes. Mangroves such as *Rhizophora* are being evaluated for their suitability in combating metal pollution. *Avicennia* is tolerant to high organic pollution. Indonesia has successfully used *Avicennia* and *Acanthus ilicifolius* in aquaculture ponds for controlling salinity and pH during the rainy season.

Management of Mangrove Nurseries

Nursery development for mangroves is of use when developing large scale planting materials. It has been suggested that the site for raising seedlings on nursery beds should be inundated by spring tides throughout the year. Pre-treatment of seeds may be needed depending on the requirement of the species. For example, the fruits of *Avicennia* must be exposed daily to tidal inundation for a week before sowing. Fruits of *Sonneratia apetala*, on the other hand, need to be soaked in saline water for 12 hours and then sun dried for another 12 hours for five days. Thereafter, the fruits are washed in saline water and the seeds recovered from the disintegrating flesh.

Young seedlings may need to be shaded during the early days of growth. However, shading should be removed for about a month before transplantation, for the "hardening" of the seedlings. Mangrove nurseries that are developed in the upper part of inter-tidal regions are naturally watered by tidal waters and so do not need to be watered. It may be necessary

though to water the seedlings once a day at neap tide. Nurseries away from the inter-tidal zone need to be watered twice a day.

The young seedlings/shoots and leaves must be inspected for pest damage. Growing seedling must be protected from crabs, caterpillars, barnacles and insects.

Planting Patterns

Plantations are of two types:

- (i) Direct seeds or propagules are directly planted in muddy areas.
- (ii) Seedlings obtained from nurseries are planted.



Afforestation of Mangroves

In places where pest infestation is severe it is recommended that nursery-raised taller seedlings be used. Also it is necessary to follow the natural zonation pattern of mangrove vegetation while planting. For example, lengthy propagules colonize along the upper tidal zone and smaller ones establish towards landward inter-tidal areas. The ideal

ones establish towards landward inter-tidal areas. The ideal time for planting is at low tide. The depth of planting can increase with the length of the propagule. The propagules are planted with their pointed tip in the soil. Small sized-seeds should be placed gently in the soil. The spacing between individual plants is usually maintained at 1.5-2 m and a long line rope may be used to maintain adequate spacing.

Planting seasons differ with different species, availability of planting materials, optimal salinity and other conditions. Planting is not recommended when salinity is high, or when waves are turbulent because of strong winds. The post monsoon season when salinity is moderate is a good time for planting.

The newly planted propagules/seedlings must be closely monitored and any damaged /dead plant promptly removed and replaced. This is necessary for the proper regeneration of mangroves. It cannot be over-emphasised, however, that while restoration is a good idea, conservation of mangrove forests is better than restoration. This can be achieved by reducing man's dependence on mangroves. Undertaking massive afforestation programmes with emphasis on the improved fuel- wood-yielding trees in the buffer areas, to sustain the requirement of the local people may hold the key.

Joint Forest Management

The involvement of local people who have a stake in the conservation and management of this unique ecosystem is desirable. It is necessary to allow people to make decisions as they are the ones responsible for the present and future state of the resources. This is broadly known as Joint Forest Management or Co-Management. In short, this is a partnership arrangement in which government, the community of local resource users, external agents (such as NGOs, academic institutions etc.) and other stakeholders (example fish traders and tourist agents) share the responsibility and authority in

Identifying Stakeholders

It is important to identify stakeholders correctly. Stakeholder characteristics may change from place to place but largely it involves the following:

- (i) *Local User Communities:* People of these communities live in and around mangrove habitats and directly draw on resources such as fish, wood, leaves and shoots etc.
- (ii) *Local Community:* People of this community do not use the mangroves as resources but live within the mangrove forests for protection against cyclones etc.
- (iii) *Remote User Communities:* People of this community may come from far away to use the mangrove areas for prawn fishing etc.
- (iv) *Government Agencies:* These have the responsibility of managing and protecting mangrove resources.
- (v) *Supporters of Mangrove-user Communities:* NGO and other Voluntary agencies
- (vi) *Research and Academic Institutions:* These monitor the state of health of mangrove forests.

In cases of genuine participation, the stakeholders are actively involved in decision-making. They directly take on planning implementation and monitoring of mangrove resources. Educating the local people about the economic and ecological values and functions of mangrove forests may blunt the negative impacts to a great degree. With better management practices, people can gather firewood for their bonafide needs in a sustainable manner.

Role of Global Institutions

Many institutions such as United Nations educational Scientific and Cultural Organizations (UNESCO), The International Society for Mangrove Ecosystems (ISME), The International Tropical Timber Organization (ITTO), ADB, CIDA, DANCED,

EU, FAO, IUCN, IUFRO, JICA, Ramsar Convention, UNDP, UNEP, USAID and Wetlands International have sponsored programmes on the conservation and management of mangrove ecosystems.

The project areas include:

- Training and capacity building
- Survey and inventurisation
- Database development
- Case studies on Tourism and Environment
- Nursery and Plantation projects in mangrove areas
- Creation of Mangrove walkways
- Establishment of protected areas
- Railway and port restructuring
- Bee-keeping in mangrove forests
- Production of global atlases and handbook for mangroves.

Ramsar Convention

This is an International Convention started in 1971 at Ramsar (Iran) to protect "the Wetlands of International Importance." About 830 Ramsar Sites have been designated by the countries that have become signatories to the Ramsar Convention. About one-third of these sites support mangrove vegetation. The parties to the Ramsar Convention have embarked on the protection and wise-use of over 15 million ha of mangrove wetland. Important sites include the Sunderbans in Bangladesh which is one of the largest continuous blocks of mangroves in the world; 35042 ha in Ecuador, 12000 ha in Suriname etc.

The International Society for Mangrove Ecosystems

This is an international, non-profit, NGO set up in 1990 with its HQ at Okinawa, Japan. Its objectives are:

- (i) To encourage and support activities leading to conservation and restoration of mangrove ecosystems,

- (ii) To provide necessary information through the Global Mangrove Database and Information System (GLOMIS) and to
- (iii) Raise funds to accelerate activities related to mangroves.

In 1991, the ISME adopted the "Charter for mangroves". It has more than 700 members in 70 countries. ISME is also involved in the propagation of species under biodiversity programme, involvement of volunteers for planting programmes, monitoring and evaluation of mangrove plantation programmes, evaluation of mangroves as coastal barrier, transfer of management skills for mangroves and international cooperation. Its GLOMIS project has four regional centres: Brazil, Ghana, Fiji and India. This project places emphasis on the exchange of information and cooperation among the scientists, government and the people for the conservation and management of mangroves of the world.

Wetland International

Founded in 1995, this organization currently counts about 47 countries as members. Its main focus is on waterfowl protection associated with mangroves.

Mangrove Action Plan (MAP)

It was founded in 1992 in USA using the networking of 300 NGOs, 200 scientists and academicians from 50 countries. The MAP aims at reversing the degradation of mangrove forest ecosystems worldwide and promoting the local community land-use rights thereby involving locals directly in a sustainable manner.

Caribbean Mangrove Network

It was founded in 1996 with 25 mangrove specialists and aims at the conservation and sustainable management of mangroves

of the Caribbean region by pooling expertise and linking institutions and resourceful people. It operates a forum for the dissemination of research results, popularizing best-management practices and sharing available information.

Indian Endeavors

Mangrove Society of India

It is headquartered at the National Institute of Oceanography (CSIR), Goa. Its responsibility is to create awareness at various levels of society so that mangroves are better protected. *Mangal-Van* is the name of the newsletter published by this Society.

The M. S. Swaminathan Research Foundation (MSSRF), Chennai with the help of the State Forest Department has been successful in introducing community participation in the management of mangroves in Tamil Nadu, Andhra Pradesh, and Orissa. The MSSRF was the first agency to propose the concept that mangroves can be the donors of breeding crop genotypes adapted to coastal salinity through recombinant DNA technology. MSSRF has contributed towards the conservation of mangroves in three ways: information, extension and research as follows:

- (a) Initiated a Mangrove Ecosystem Information Service (MEIS)
- (b) Initiated effective technique to restore mangrove degradation, with active participation of mangrove-dependent populations and respective Government Departments.
- (c) Pioneered studies on biotechnological aspects of mangroves including aspects such as: genetic mapping and modifications, biomonitoring and bioremediation and micropropagation.

Table: Mangrove Areas of India Under Management Action Plan		
S. No.	Mangrove area under conservation	State
1.	Sundarbans	West Bengal
2.	Bhitarkanika	Orissa
3.	Mahanadi	Orissa
4.	Subernarekha	Orissa
5.	Devi	Orissa
6.	Dhamra	Orissa
7.	Kalibhanj dia Island	Orissa
8.	Coringa	Andhra Pradesh
9.	East Godavari	Andhra Pradesh
10.	Krishna	Andhra Pradesh
11.	Pichavaram	Tamil Nadu
12.	Kazhuveli	Tamil Nadu
13.	Muthupet	Tamil Nadu
14.	Ramanad	Tamil Nadu
15.	Achara-Ratnagiri	Maharashtra
16.	Devghadh	Maharashtra
17.	Vijaydurga	Maharashtra
18.	Mumbra-Diva	Maharashtra
19.	Vaitrana River	Maharashtra
20.	Kundalika-Revdanda	Maharashtra
21.	Vasai-Manori Creek	Maharashtra
22.	Shreevardhan-Varal-Turumbadi & Kalsuri	Maharashtra
23.	Chorao	Goa
24.	Northern Andamans	Andaman & Nicobar Islands
25.	Northern Nicobar	Andaman & Nicobar Islands
26.	Gulf of Khambhat	Gujarat
27.	Gulf of Kachchh	Gujarat
28.	Coondapur	Karnataka
29.	Honnavar Division	Karnataka

Mangrove Project of the Godrej Group of Industries

This is the first privately managed wetland programme in Asia. It is also probably the first of its kind to get the ISO 14001 certificate. With the assistance of the World Bank, mangroves have been planted on 100 acres and more than 500 wild animals have been rehabilitated on the site, located in Mumbai. An interpretation site has been set up, along the creek site of Thane, to impart education and spread awareness about mangroves.

Government Participation

It is agreed that the Government should encourage and involve ecologists, researchers and specialists to work on the various aspects of ecological management of this valuable resource. Re-afforestation of the decimated mangroves should be taken up on a priority basis. Certain mangrove habitats should be declared "Reserved areas". Only then can we be certain that these especial plants will survive and continue to play their role in the global cycles that, in the final analysis, impact on the future of the Earth and all on it.

Of course, the first step to protect mangroves predates Independence when the first management plan for mangroves was introduced in 1892 for the Sunderbans Mangrove forests.

It is heartening therefore to note that the Government of India has taken proactive steps in this regard. In 1979, the Department of Environment and forests constituted a National Committee for research, development and management of coastal environment. The committee was also entrusted with the task of advising the Government on appropriate policies and action plans for the conservation of mangroves; advising on research and training on mangroves; suggesting selective areas for conservation and helping the Government in the development of collaborative projects with international

funding agencies and inter-governmental bodies in the field of mangrove conservation.

Steering Committees along the lines of the National committee have also been constituted at the state levels since 1986. The Management Action Plan includes: afforestation; regeneration of degraded mangrove areas; protective measures; eco-development; education and awareness related to

Table: State-wise list of Mangroves areas identified by the Ministry

State / UT Mangrove Area	
West Bengal	• Mangalore Forest Divisions • Karwar
• Sunderbans	
Orissa	Goa
• Bhaitarkanika, • Mahanadi, • Subernarekha, • Devi, • Dhamra, • MGRC, • Chilka • Coringa, • East Godavari, • Krishna • Pulicat, • Kazhuveli	• Goa
	Maharashtra
	• Achra-Ratnagiri, • Devgarh-Vijay Dur, • Veldur, • Kundalika-Ravdana, • Mumbra-Diva, • Vikroli, • Shreevardhan, • Vaitarna, • Vasasi-Manori, • Malvan
Andaman & Nicobar	Gujarat
• North Andamans, • Nicobar	• Gulf of Kutchh, • Gulf of Khambat, • Dumas-Ubhrat
Kerala	Tamil Nadu
• Vembanad, • Kannur	• Pichavram, • Muthupet,
Karnataka	
• Coondapur, • Dakshin Kannada/Honnavar,	

conservation of mangroves with a view to reduce human pressures.

The Government of India has given top priority to community participation in the conservation and management of mangroves. It has initiated the establishment of National Mangrove Genetic Resource Centre at Kalibhanja in the Bhitarkanika mangrove forests of Orissa. Many Government Departments fund mangrove research programmes. For example, the Department of Science and Technology (DST), Department of Earth Sciences and Department of Biotechnology (DBT), the University Grants Commission (UGC) State Forest Departments, social organizations, Wildlife Advisory Boards, Marine Park Authorities and World Wildlife Fund (WWF) –India, all have robust programmes in this field.

Biosphere Reserves

Biosphere Reserves are areas of terrestrial and coastal ecosystems which are internationally recognized within the framework of UNESCO's Man and Biosphere (MAB) programme. These Reserves are rich in biological and cultural diversity and encompass unique features of exceptionally pristine nature. The goal is to facilitate conservation of representative landscapes and their immense biological diversity and cultural heritage, foster economic and human development which is culturally and ecologically sustainable and to provide support for research, monitoring education and information exchange.

The Ministry of Environment and Forests has provided financial assistance to the State Governments for conservation and management of Biosphere Reserves. One such Biosphere Reserve is at Sunderbans (West Bengal). The Ministry of Environment & Forests had launched the Mangrove Conservation Programme as far back as in 1987. The Ministry

has so far identified 38 mangrove areas for intensive conservation and management in the country. These areas were identified on the recommendation of National Committee on Mangroves & Coral Reefs on the basis of their unique ecosystems, biodiversity etc. Cent percent central assistance is given under Management Action Plans (MAPs) for undertaking activities such as raising mangrove plantations, protection, catchments area treatment, siltation control, pollution abatement, biodiversity conservation, sustainable resource utilization, survey & demarcation, education & awareness etc. This is further supplemented by research and developmental activities which can give scientific inputs for smooth execution of Management Action Plans.

In India, some mangrove forests get total protection under MPAs or as Marine Protected Areas. There are 26 MPAs, which include 17 Sanctuaries and 9 National parks and mangroves areas that fall within the precincts are well protected. The Sunderbans now form the Natural World Heritage Site and this enjoys the distinction of being the first mangrove forest to be so declared for the protection of its wildlife.

There are about a dozen major institutions in India that are engaged actively in mangrove research. Most such projects in India tackle management-related issues. Important programmes include those on survey and distribution, remote sensing, eco-biology, fisheries, aquaculture, physiology, soil, pollution, productivity, afforestation, management and wildlife. Since 1992, scientific literature on mangrove ecosystems has been collected and disseminated through the Environmental Information System (ENVIS) at the Annamalai University. The Ministry of Environment and Forests provides financial assistance. The National Institute of Oceanography (CSIR) at Goa maintains an informative website about mangroves.

Glossary

Abundance: The number of individuals of a given species in a region.

Active restoration: Requiring manipulation by humans for successful colonization and /or establishment of organisms and ecosystem functioning.

Adaptation: Any genetically controlled characteristic that increases an organisms's fitness, usually by ensuring the organism to survive and reproduce in the environment it inhabits.

Aerenchyma: Porous tissue, especially well developed in wetland plants that allows diffusive flux of oxygen from above ground tissues to root tips. This tissue both supports the respiratory demand of the root tissues and allows oxygen to leak into the surrounding soil.

Aerial roots: In mangrove species such as *Rhizophora*, roots branch out from the stem some distance above the soil surface. Pores in the aerial portion of these roots enable gas exchange to take place, through aerenchyma tissue, with the respiring underground portions of the root.

Aerobe: An organism that utilizes or requires the presence of oxygen for growth.

Afforestation: The process of planting trees in areas currently devoid of them. It is done regions especially mangroves.

Algae: Primitive plantlike organisms that photosynthesize. These organisms can be unicellular, filamentous, or colonial microscopic forms, or macroscopic, consisting of a primitive plant body (thallus) that lacks vascular tissue in most species.

Amphibian: Member of a class of vertebrates comprising frogs and toad and salamanders, which typically return to water to breed and pass through an aquatic larval stage with gills. Amphibians have a moist skin without scales, which is permeable to water and gases.

Anaerobe: An organism able to grow in the absence of oxygen.

Angiosperms: Flowering vascular plants in which the seeds, which are produced from the ovules of the flowers, are enclosed in fruits developed from the matured ovaries

Annelida : Segmented worms, a relatively species-poor phylum.

Anthropogenic: Caused by human; related to the activities of human beings.

Arthropoda : Joint –legged animals, the most species rich phylum existing today.

Autotrophic: Describing an organism able to utilize carbon dioxide as its source of carbon.

Bacteria: One of three domains of life. Prokaryotic cells; formerly called eubacteria.

Back water: Water moved backward or held back by a dam, tide etc.

Benthic: Living or located at or on the bottom of the sea, streams, lakes, or riverbeds, or another aquatic environment.

Bio-diversity: The variability among living organisms from all sources and the ecological systems of which they are a part.

Biogeochemical cycle: Pathways and storage of chemical elements on the chemistry of the environment and geochemical controls on the structure and function of ecosystems.

Brakish : Less salty than sea water; somewhat salty.

Calcareous forms: The term variously used for wetlands with high calcium carbonate in water and soils.

Calcification: The deposition of calcium carbonate skeletons by aquatic plants or animals. In reef –building corals, calcium is deposited in its aragonitic mineral form.

Chemoautotrophs : Organisms able to synthesize organic compounds by the oxidation of energy-rich inorganic sources.

Coastal: Describing estuaries, semi-enclosed seas, and shallower regions of the ocean, including areas influenced by rivers and runoff from land.

Coral reef : Benthic environments characterized by reef building corals with symbiotic dinoflagellates.

Creek : A notable physiographic feature of salt marshes, especially low marshes, in the development of tidal creeks in the marsh itself. These creeks develop, as do rivers “with minor irregularities sooner or later causing the water to be deflected into definite channels”.

Cryptovivipary : The seed of plants like *Avicennia* does not break of the fruit wall until it falls from mother plant.

Decomposition : The biotic breakdown of dead organic matter by bacteria and fungi that releases carbon dioxide and nutrients for recycling.

Deforestation : The complete or almost complete removal of tree cover and conversion of forested land to other uses as a result of human activities.

Degraded : Describing an area with a loss of forest structure, productivity, and native species diversity.

Depletion : In mangroves, reduction of plant species threaten future productivity.

Detritivorous : Organisms that consume dead plant or animal material.

Detritus : Nonliving organic matter in both soluble and particulate forms; dead organic matter.

Dispersal : The movement, or spread , of an organism from one area to another independent from other organisms and of historical events that change the natural distribution of the organism. Specifically, the movement of an individual organism away from its place of origin to the place where it breeds.

Diversity: The variety of species within a given taxonomic group.

Dormancy: Any state of reduced metabolic activity of an organism.

Dormant: Describing a condition under which a seed will not germinate, even if all environmental requirements for germination are met.

Ecosystem: A community of organisms (plants, animals and microbes) and their physical environment interacting as an ecological unit, such as a lake, a wetland, a forest etc.

Endangered: Describing a species that is at substantial risk of extinction as a result of human activities.

Endangered species: Species that are likely to become extinct in the near future because of normal human activities.

Estuary: Semi-enclosed coastal body of water that has a free connection with the open sea and within which seawater is measurably diluted with freshwater derived from land drainage.

Estuarine: Formed or deposited in estuary.

Fauna: The animal species living in a defined area.

Food chain: A representation of the links between consumers and their resources.

Forest degradation: Damage to forest ecosystems through human activities that does not result in the total elimination of forest cover.

Green house effect : Green house gases traps radiant energy in the lower atmosphere and makes the earth warmer.

Habitat : The type of environment in which an organism or species lives, grows, and reproduces.

Insular : Convergence of small estuary, backwaters support mangroves.

Intertidal zones : Pertaining to a shore zone bounded by the level of low and high tide.

Inventorization : Act of making special list or stock

Knee roots : Some mangrove plants like *Bruguiera* produces roots looks like human knee.

Lagoons : These are coastal bodies of water, partly separated from the sea by barrier beaches or bass of marine origin. As a rule, lagoons are elongate and lie parallel to the shoreline. They are usually characteristic of, but not restricted to, shores of emergence. Lagoons are generally shallower and more saline than typical estuaries.

Lenticels : These are specialized pores seen in the surface of aerial roots of some mangroves.

Mangal : A term sometimes used to specify the mangrove habitat.

Mangrove : A collective term for environments characterized by mangrove trees.

Marshes: A frequently or continually inundated wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions. In European terminology a marsh has a mineral soil substrate and does not accumulate peat.

Microbes : Single celled organisms , such as bacteria, archaea, protists, and unicellular fungi.

Neritic : Ecological zone of the continental shelf extending from low tide to a depth of 180 metre.

Niche : An organisms's biotic and abiotic resource requirements, collectively enabling the organism's trophic and behavioral role in the community.

Phylogenetic : Pertaining to the true pattern of relationship, usually expressed in the form of a binary branching tree .

Phytoplankton : Unicellular and chain-forming algal plants that are suspended and transported in the water above the bottom.

Pneumatophodes : Pores present on the surface on aerial breathing roots of some mangroves.

Pneumatophores : Aerial roots of some mangroves , grow vertically above the soil surface , enabling gas exchange to take place with the underground roots.

Predator : A predatory person or animal.

Propagules : Seed or unit of an organism to develop into young one.

Reserved areas : Areas of forest selected for specific purpose especially to protect and develop the flora and fauna.

Salt glands : A special type of glands present in the leaves of some mangroves helps to secrete out the excess salt.

Siltation : The accumulation of silt in the bottom of waterways or bodies of water.

Tidal wave : Waves caused by strong winds and not related to the tides.

Tsunami : A huge sea wave caused by a great disturbance under an ocean, as a strong earth quake or volcanic eruption.

Typhoon : Any violent cyclone.

Vivipary : A condition seen in some mangroves that seed develops to some extent while it remains with the mother plant.

Zonation : The occurrence of single species or groups of species in recognizable bands that might delineate a range of water depth or a range of height in the intertidal zone.

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